CCADET
CENTRO DE CIENCIAS APLICADAS
Y DESARROLLO TECNOLÓGICO

ISSN 2395-8499

SOMI
CONGRESO DE INSTRUMENTACIÓN
XXX

AÑO 02, No. 01
octubre 2015

A basket aerodynamics prototype design for a centrifuge

G. Ramírez-Zúñiga, Guillermo Hernández-Cruz, Eduardo Ramos, J. Antonio Castillo
Instituto de Energías Renovables
Privada Xochicalco s/n, Temixco, Morelos, México.
guraz@ier.unam.mx; ghc@ier.unam.mx; erm@ier.unam.mx, jadat@ier.unam.mx
Minerva Vargas
Instituto Tecnológico de Zacatepec
Calzada Tecnológico No. 27, Zacatepec de Hidalgo, Morelos, México.
minerva.vv@itzacatepec.edu.mx

ABSTRACT

Fluid mechanics and heat transfer research are realized under enhanced gravity conditions in a centrifuge. Its aim is know the gravity effect over different phenomena like as natural convection, drop evaporation, etc. At ends of each arms of the centrifuge is located a container or basket in order to carried different experimental setups inside it. Currently research experiments are increased and its complexity hence demand a newer centrifuge with better performance. Aim of this work present a basket design, its manufacture process and visualization flow pattern around an aerodynamic basket prototype. This feature is related NACA-64A210 profile and $\frac{X^n}{a^n}+\frac{Y^n}{b^n}=1$ equation.

Keywords: Centrifuge, enhanced gravity, NACA profile, aerodynamics, water channel.

♦ 1 INTRODUCTION

Research activities on the Thermoscience Department of the Renewable Energy Institute IER-UNAM are related heat and mass transfer and fluid dynamics phenomena. In order to analyze the effects of the terrestrial gravity acceleration g = 9.81 m/s^2, a centrifuge with 14g was constructed [1]. Previous experiments were done under a broad range of gravity lower than 14g [2-4]. With the science advancement in fluid mechanics, nowadays, new kind of complex experiments are proposed. Figure 1 shows some examples of the versatile experimental setups as: Point Diffraction Interferometer and Stereoscopic Particle Image Velocimetry (SPIV).

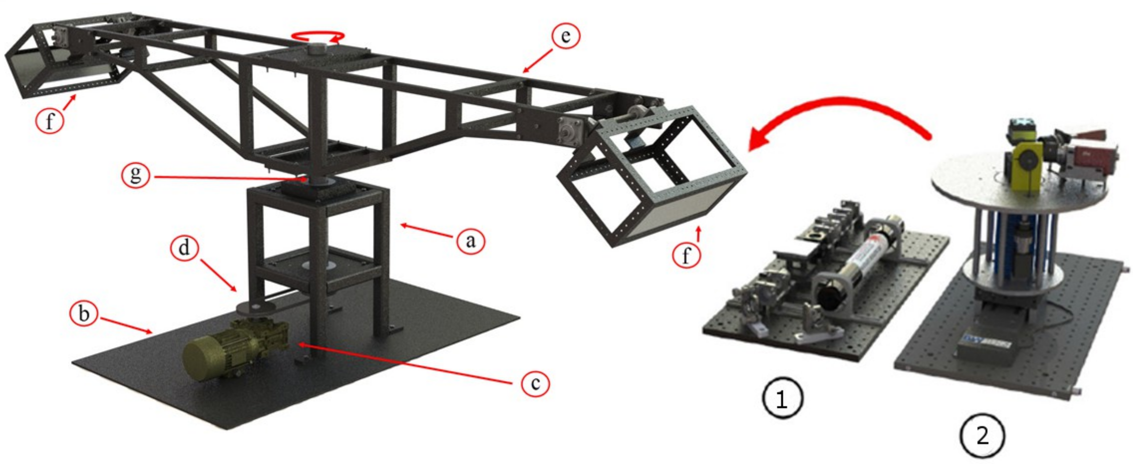

Figure 1. Centrifuge and its components. a) Centrifuge basement, b) Anti-vibration foundation c) Three phase motor, d) Belts, e) Arms and rotating structure, f) Baskets or gondolas, and g) Rotation shaft. 1. Point diffraction interferometer and 2. Experimental equipment of Stereoscopic Particle Image Velocimetry.

One of the several technical restrictions to use these new experimental setups in a centrifuge is the inner basket space, in addition to its weight and energy consumption. Hence, a redesign of a new centrifuge and baskets is required. An alternative structure of the new centrifuge will be constructed to operate at 20 g, its construction is ongoing at CCADET-UNAM. In addition-newer baskets have been designed to support 20 g, experiments and equipment weights. Aerodynamics has been considered in the design to minimize vibrations with air flow around the basket when it spins.

♦ 2 AERODYNAMICS AND MECHANICAL DESIGN

The basket design in frontal and rear section is based on NACA-64A210 profile. Modifying it in such a way that it is symmetrical. The result is shown in Figure 2. The new modified 2D geometry of the NACA-64A210 profile is divided to get the frontal and rear parts of the basket (Figure 3).

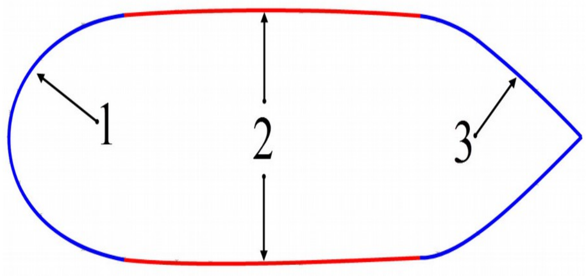

Figure 2. 2D NACA-64A210 modified profile, 1) frontal part, 2) intermediate part and 3) rear part

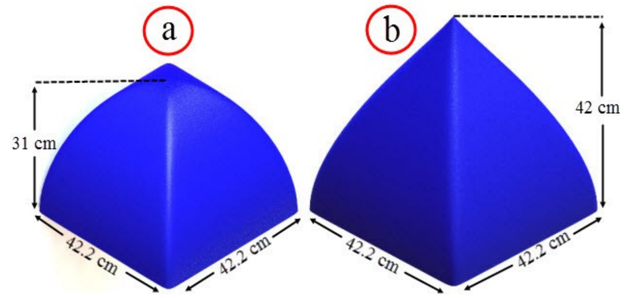

Figure 3. Three-dimensional representation, frontal (a) and rear (b) section of the profile.

Additionally we used the expression 1, to fit the 2D geometry of the NACA profile to a cross section of the intermediate section of the basket.

$$\frac{X^n}{a^n}+\frac{Y^n}{b^n}=1 \quad (1)$$

MatLab software was used to generate the 3D profiles and Solidworks software for CAD models to fitting assembling parts.

The internal structure of the basket supports total weight experimental equipment, it has been designed with following technical conditions:

1. Weight of the experimental equipment: 10 kg.
2. Total weight of the basket: 26 kg.
3. Resultant acceleration of the basket: 20 g (g = 9.81 m/s), 196.2 m/s2
4. Dimensions of the intermediate section (enclosure for the experimentation) of the basket: length 0.60 m, width 0.402 m and height 0.402 m.

Taking into account the above requirements, it has been decided to use an anodized aluminum material 6063-T6 (IPS profile of 40x40 mm). In addition has been used: standard fasteners, reinforced corners of aluminum 6063-T6, reinforcing standard angles and high-strength bolts. Figure 4 shows the geometry of the internal structure of the basket (rectangular geometry).

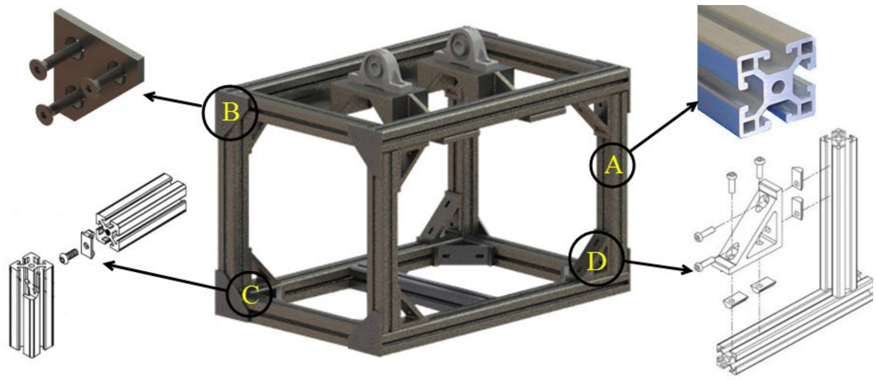

Figure 4. Internal structure of the basket, A) IPS profile 40x40 mm, B) reinforced corner, C) assembly by high-strength bolts, and D) assembly of the structure which reinforcing standard angles.

Structural design is verified and validated using the Finite Element Method for the analysis of mechanical stress with SolidWorks software. Figure 5 shows the assembly of the basket, which consists of a fiberglass cover (front and rear parts of the profile, cover of the intermediate section and a lid) and the internal metallic structure. The photography of the intermediate metallic structure and the final assembly basket are shown in Figure 6.

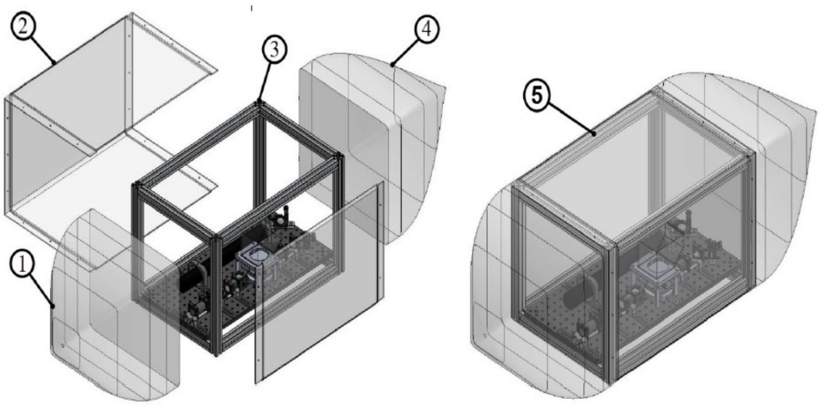

Figure 5. Basket section. 1) Frontal part, 2) intermediate section, 3) metallic structure, 4) rear section, y 5) basket assembly.

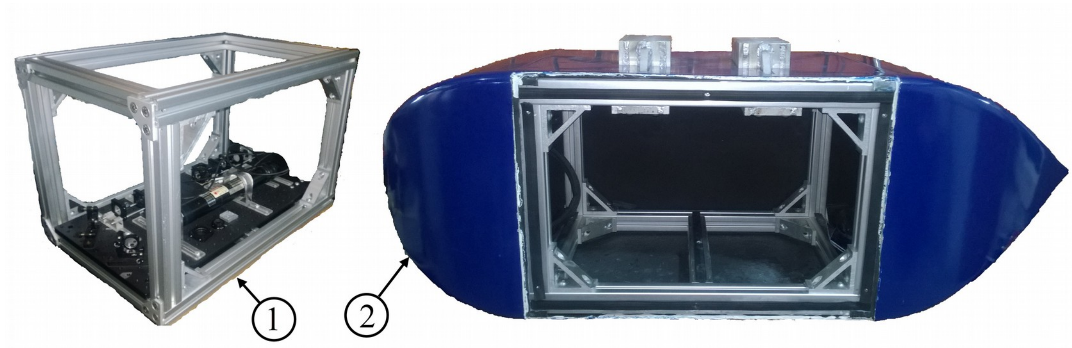

Figure 6. 1) Intermediate structure basket, 2) aerodynamic basket

3 AERODYNAMICS GEOMETRY VALIDATION

At increased gravity conditions, the aerodynamics geometry of the basket is a crucial factor. Pressure forces over frontal surface of the container produce vibrations when it spins at higher angular velocities greater than 60 RPM. This effect is modified if the basket has an aerodynamics profile and a lighter material cover with minimal roughness. The aerodynamics features of the basket profile are determined, in full scale, by Reynolds number Re_{fs}. The Re_{fs} = 1.5x10^6 at 20g, is calculated by using real conditions of the velocity U_{fs} = 19.16 m/s, the characteristic length of the basket L_{fs} = 1.3 m, the air density ρ = 1.1839 kg/m^3 and the viscosity μ = 1.846 x 10^{-5} kg/ms at 25 C [5]. The arm length 1.87 m, is a distance from center of the axis of the centrifuge to basket floor. Last condition is considered if the position of the container is aligned with the centrifuge arms.

♦ 4EXPERIMENTAL SET UP

The experimental setup is composed of an open water channel (OWC), a scaled model, and a SPIV measurement system. The OWC, with glass walls, has a length of 6.00 m, height of 0.50 m, and width of 0.315 m. The test section has a length of 1.00 m, beginning at 4.0 m from the water inlet (Figure 10a). At the inlet, the OWC has a settling chamber to reduce transverse and vertical turbulence intensity and velocity differences. A curved ramp is placed at the end of the OWC to maintain a constant water depth of 0.41 m and to reduce the water outlet influence on the test section. The scaled model (Figure 10b), in scale 1: 7, was made of polylactic acid (PLA). At OWC test section, the scaled model produce a recommended blockage ratio below 2.7% [6]. A SPIV system was used to measure the three velocity components on the center plane of the flow (Figure 10b). The system is composed of a twin-cavity Nd-YAG laser (New Wave RESEARCH Solo120 XT-15 Hz) with integrated optics for a light sheet output, two digital high resolution cameras (Nikon AF NIKKOR 50 mm 1:1.4 D) and a high-precision electronic controller (LaVision VC-ImagerPro 2M) that synchronizes the laser pulse emission with the camera shots. The control, data acquisition and the processing were done by using LaVision Davis 7.2 program [7]. For each experiment, a total of 90 velocity vector fields were taken with an interval of 0.04 s.

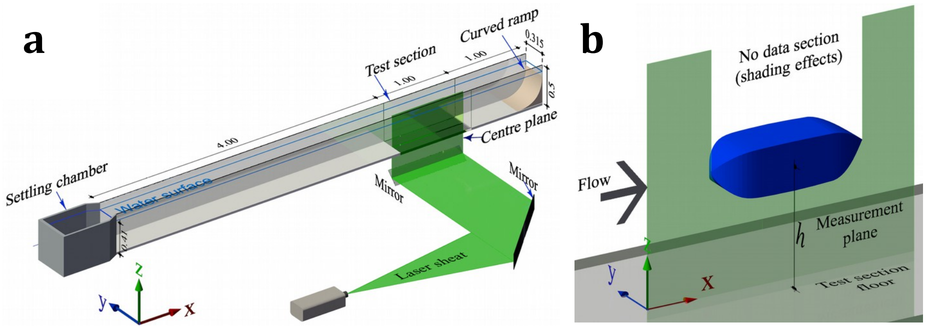

Figure 10. Open water channel sketch: (a) Perspective view with dimensions, units in meters; (b) Test section, scaled model height above the test section floor h = 0.15 m and measurement centerplane.

♦ 5 EXPERIMENTAL RESULTS

The dynamic similarity was applied with Reynolds number, in small scale, $Re_{sc} = u_r L_r / v$ = 2.20 x 10^4 where u_r = 0.106 m/s is the reference wind velocity at the scaled model height above the test section floor h = 0.15 m (Figure 11b), L_r = 0.0875 m is the characteristic length geometry of the basket and $v = 8.94 \times 10^{-7}$ m^2/s is the kinematic viscosity at the water temperature T_w = 25 ºC. In the OWC test section, the profiles of the vertical velocity *U(z)* and the intensity turbulence *I(z)* were achieved, in accordance with an uniform mean velocity profile and low turbulence intensity, by using a honeycomb at the settling chamber. The profiles, shown in Figure 11a, are representative for the case where only the basket is moving and where the speed of the surrounding air is zero [6]

The internal structure of the basket supports the total weight experimental equipment and it has been designed with following technical conditions. The reference mean wind speed U_r and a reference turbulence intensity I_r = 6 % were measured at h.

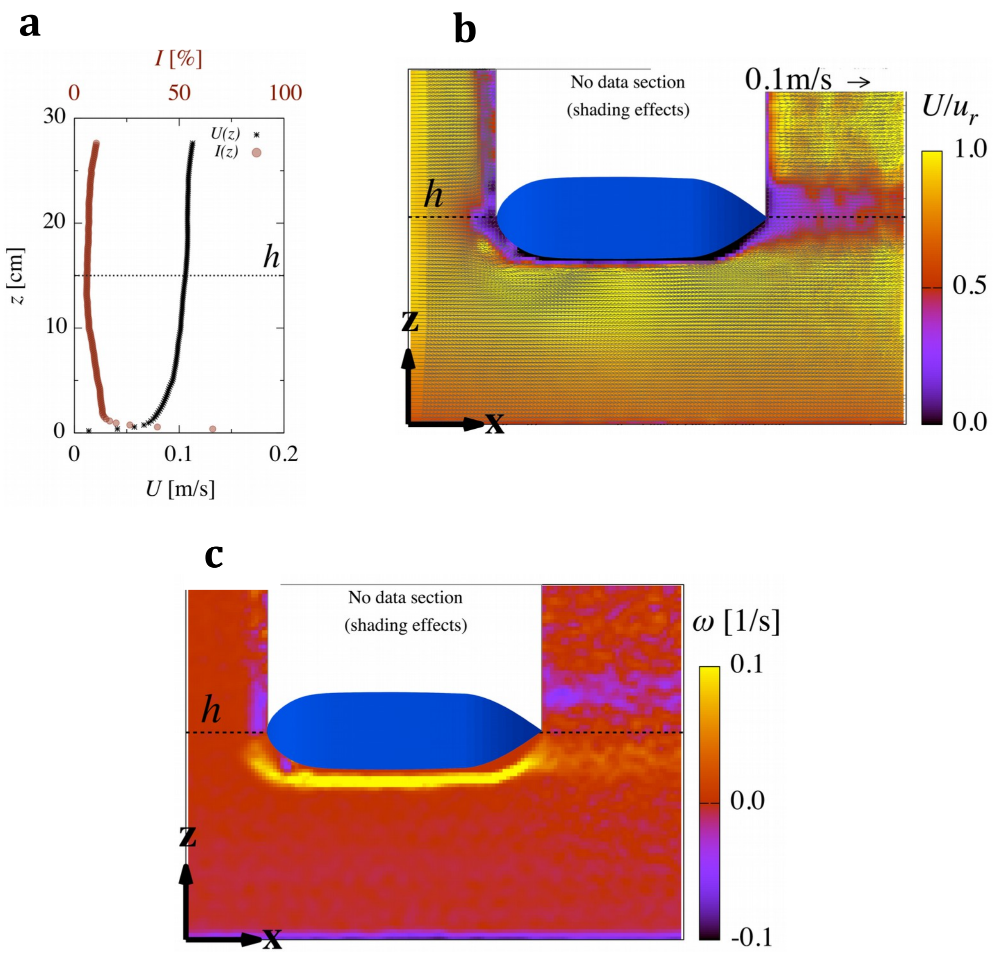

Figure 11. (a) Velocity *U* and Turbulence Intensity *I* vertical profiles. (b) Velocity vector and velocity magnitude maps at vertical centerplane. (c) Vorticity map at vertical centerplane.

The velocity vector and velocity magnitude maps in the vertical centerplane are shown in Figure 11b. It can be observed that the boundary layer is conserved along the model surface. In the tail of the model a wake is formed with an average velocity factor below 0.5 respect to u_r. Figure 11c shows the vorticity map in the vertical centerplane. Two cylindrical structures are formed in the flow direction, the first positive in the upper model surface and the second negative in the lower model surface. The structures are present from the head until the tail. In Figures 11b and 11c, a white area has no experimental data as a result of shading effects. The experimental results show a velocity vertical component lower than the streamwise velocity component that indicates an aerodynamic shape successfully designed.

♦ 6 DISSCUSION

The experiments were carried out in an open water channel using scale models. SPIV shows lower resolution close to the model faces which is caused by the shading effects. Hence, the complete interaction of the basket geometry with the fluid, presented in this work, can not be calculated at this stage of the research. It is expected that future CDF simulations could help to calculate it.

♦ 7 CONCLUSIONS

It has built a basket of 1.3 m in length, with a cross section of square 0.402 m. This basket has a profile similar to a NACA airfoil geometry. In tests on a scale model (1: 7) into an open water channel, it is certain that the air flow around the basket does not generated vortices. Therefore no vibrations are generated, the primary purpose of geometry designed aerodynamics.

8 Acknowledgements

The authors would like to thank to J.A Cruz-Martínez, J.A.Flores Neri, F. Navarro Martínez, M. Flores López in the support of the basic study in the aerodynamics, mechanical and electrical basket design. To Jaime Lopez by machined basket and technical assistance.

REFERENCES

[1] Vargas M., Ramos E. Ascanio G., Espejel R., Esquivel G. Hernández-Cruz G.. A centrifuge for studies a fluid dynamics phenomena in a rotating frame of reference. Revista Mexicana de Física, 2002, 48, 3, 255-266.

[2] Vargas M. Rincón M.E., Sanchez Tizapa M. Ramos E. Mesoporous titanium oxide carbon nanotubes soot films dreid under gravity and supergravity conditions. 2008, AIP Conference Proceedings.

[3] Ordeñana-Martínez A.S., Rincón M.E., Vargas M., Estrada-Vargas A., Casillas N. , Bárcena-Soto M. Ramos E. Carbon nanotubes/carbon xerogel-nafion electrodes: a comparative study of preparation methods, J. Solid State Electrochem, 2012, 16, 12, 3777-3782.

[4] Ordeñana-Martínez A.S., Rincón M.E., Vargas M., Ramos E. Impedance response of carbon nanotube–titania electrodes dried under modified gravity, Thin Solid Films, 2011, 519,16, 5403–5407.

[5] White F., Fluid Mechanics, Fifth edition McGraw Hill, 2010.

[6] Toparlar Y, Blocken B., A following car influences cyclist drag: CFD simulations and wind tunnel measurements. Journal of Wind Engineering and Industrial Aerodynamic, 2015, 145, 178-186.

[7] LaVision (Ed.): Product-Manual for Davis 7.2. Flow Master Getting Started, 2006, LaVision GmbH, Göttingen.